Special Issue for International Conference of Advanced Materials Engineering and Technology (ICAMET 2013), 28-29 November 2013, Bandung Indonesia

**Advances in Environmental Biology**, 7(12) October Special Issue 2013, Pages: 3826-3834

AENSI Journals

**Advances in Environmental Biology**

Journal home page: http://www.aensiweb.com/aeb.html

# Utilization of Palm Oil Waste into Fired Clay Brick

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A R T I C L E I N F O

***Article history:***
*Received 11 September 2013*
*Received in revised form 21 November 2013*
*Accepted 25 November 2013*
*Available online 3 December 2013*

***Key words:***
*Recycling Waste, Palm Oil Waste, Fired Clay Brick, Physical-Mechanical Properties, Energy Efficiency*

A B S T R A C T

Malaysia is one of the largest palm oil producers, contributing approximately 50% of the world palm oil production. In the process of palm oil extraction, biomass materials such as Palm Fibre (PF), Palm Kernel Shell (PKS) and Palm Oil Fuel Ash (POFA) are produced annually and increasingly becoming a threat to the environment. This study investigated the utilization of three types of palm oil waste (POW) into fired clay bricks. The effects of POW incorporation on the properties of bricks were determined. Bricks were manufactured by incorporating 3% of different types of POW (PKS, POFA and PF) and fired at 1050°C with a heating rate of 1°C/min. All bricks were tested for their physical and mechanical properties including drying and firing shrinkage, dry density, initial rate of suction, compressive strength and thermal conductivity. In addition, energy efficiency of the brick firing process was also calculated from its calorific value. All three types of POW decreased the manufactured bricks' compressive strength but increased their dry shrinkage and initial rate of suction (IRS) as a result of increased porosity value. Nonetheless, the incorporation of POW into a clay brick has improved its thermal conductivity properties and energy efficiency during manufacturing. In conclusion, POWs can be considered for producing lightweight fired clay bricks as they could act as pore formers to improve the thermal properties and energy efficiency in brick firing process.



**To Cite This Article:** Aeslina Abdul Kadir, Nur Azian Mohd Zahari, Noor Azizi Mardi., Utilization of Palm Oil Waste into Fired Clay Brick**. *Adv. Environ. Biol., 7(12),*** *3826-3834, 2013*

## INTRODUCTION

Palm oil is in high demand as a cash crop in several tropical countries, particularly in Malaysia, Thailand and Indonesia. In Malaysia for instance, oil palm plantation has become one of the country's success stories in agricultural development. From a humble beginning in the early 1920s, the industry then developed rapidly between 1960 and 1980. In 2008 alone, Malaysia had produced 17.7 million tons of palm oil on 4.5 million hectares of land [12]. Over half of the world's total palm oil today derives from the oil palm industry in Malaysia.

As a result of the booming industry, thousands of tons of palm oil waste (POW) are being produced annually by 200 palm oil mills in Malaysia. A considerable amount of solid waste in the form of fibres, kernel shells and empty bunches [13] discharges are produced during palm oil processing. These wastes are simply disposed without any commercial return [2].

Currently, shells and fibre wastes are used extensively as fuel for the production of steam in palm oil mills as means for waste disposal and energy recovery. After combustion however, about 5% of ash weight are produced. This ash is collected from the boiler, but because it lacks sufficient nutrients to be used as a fertilizer, the waste is dumped onto open fields near the mills. The light, small particles of the ash are easily carried away by wind, resulting in smog on a humid day. Smog then becomes an environmental issue, since it jeopardizes human's health and traffic safety. Hence, disposal of this waste becomes equally necessary.

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Additionally, the nation's pollution problem caused by the oil palm sector is exacerbated by an annual production of 4 million tons of solid waste in the form of oil palm shells [18]. A large area is required for the disposal of these POW materials, namely the palm fibre (PF), the palm kernel shell (PKS) and the palm oil fuel ash (POFA). Palm fibre (PF) is a natural fibre extracted from palm oil vascular bundles in empty fruit bunch (EFB) through a deportation process. It is a non-hazardous biodegradable material [16]. On the other hand, PKS is difficult to decompose and has been reused as mulch. According to Ortiz *et al*. [15], approximately 5 tons of shells is obtained from 66 tons of fresh fruit bunches (FFB). PKS has high grade solid, low ash and low sulphur content. Palm oil fuel ash (POFA) in addition, is the ash produced from the husk fibres and shells, during palm oil burning. A generation plant boiler is used to supply energy to the mill in order to extract the oil.

POW is a problem to the palm oil industry when it is not reused. Its accumulating disposal on landfills is becoming a prime environmental issue. Consequently, the government has to assign more hectares of land for the huge waste disposal, leading to further financial losses incurring from necessary transportation and maintenance.

Sustainable environment can be promoted by proper consumption or recycling of POW materials. Hence, recent decades have witnessed the increasing number of studies being done on recycling of agricultural waste [14] particularly as potential alternatives to building materials. When properly processed, waste materials can effectively function as construction materials that readily meet the design specifications.

To demonstrate, many researchers have attempted to incorporate wastes into the production of bricks. Due to its flexible properties, brick has become one of the most common building materials [11]. Among the wastes used for experimentations were pineapple leaves (PF) and oil palm fruit bunch (OF) [6]; vegetable matter [17]; ashes from the burning of dried mango tree and sawdust from mahogany wood [9]; wood sawdust (WSW) [19]; process waste tea (PWT) [7] and kraft pulp [8]. Incorporating agricultural wastes into bricks has not only been evidently advantageous, but is known to improve the material's performance as well. Following this, interests in the development of new composite continue to grow, enhancing further the optimal utilization of natural and particularly renewable resources.

This study investigated the possibility of incorporating different types of POW (Palm Kernel Shell (PKS), Palm Fibre (PF) and Palm Oil Fuel Ash (POFA) into fired clay bricks. This paper hence, discusses the physical and mechanical properties, thermal properties and energy efficiency of the fired clay brick containing these wastes.

## MATERIALS AND METHOD

*Preparation of Raw Materials:*

Clay soil was used as raw material. Upon delivery, the soil was stored in closed containers before being oven-dried for 24 hours at 105ºC. Once the drying process was completed, the dried soils were immediately transferred to containers to be used in laboratory test. The soil was sieved to ensure purity.

Before brickworks' commencement, the soil was first classified according to BS 1377: PART 2 (1990). Under this classification, soil type is determined by the test of plastic limit (PL) and liquid limit (LL). Table 1 shows the results of the soil's physical properties.

**Table 1:** Properties of the soil used in making fired clay bricks.

| Soil Physical Properties | Test Result |
|---|---|
| Liquid Limit (%) | 31.4 |
| Plastic Limit (%) | 23.21 |
| Maximum Dry Density (mg/m3) | 1.7 |
| Optimum Moisture Content (%) | 17 |
| Soil Classification | Silty Clay or Clayey Silt |

In this study, PKS, POFA and PF as shown in Fig. 1 (a) (b) (c), were obtained from the Penggeli Palm Oil Mill, Bandar Tenggara, Johor. POFA and PF were used at its natural state while PF was cut into smaller pieces.

**Fig. 1(a):** Palm fibre (PF).

**Fig. 1(b):** Palm kernel shell (PKS).

**Fig. 1(c):** Palm oil fuel ash (POFA).

*Manufacturing Process of Fired Clay Brick:*

There were four types of bricks manufactured for this study, namely the POFA brick, PKS brick, PF brick and control brick. To produce a control brick sample, clay soil and distilled water were weighed and mixed for 30 minutes by using the Kenwood mechanical mixer of 10-litre capacity. The same step was repeated to make POFA brick, PKS brick and PF brick, except with the incorporation of 3% of their respective waste type into the mixture. Then, the samples were pressed into moulds according to the desired shape and compacted further. Hand-operated soil compacter was used at a consistent pressure of 3000 psi. The newly-produced raw bricks must be dried before being fired. Specifically, they were dried naturally for 24 hours at room temperature before being parched further in a 105°C oven for another 24 hours. By using a heating rate of 1°C/min, the bricks were then, fired in a furnace at 1050°C. Table 2 below shows the ratio of distilled water and soil in samples with different types of POW.

**Table 2:** Ratio of POW, Clay soil and water in sampled bricks.

| Type of POW | Percentage of POW (%) | POW (kg) | Clay soil (kg) | Total Raw Material (kg) | Amount of Distilled Water (ml) |
|---|---|---|---|---|---|
| PKS | 3 | 0.090 | 2.910 | 3.000 | 540 |
| POFA | 3 | 0.090 | 2.910 | 3.000 | 540 |
| PF | 3 | 0.090 | 2.910 | 3.000 | 540 |

*Physical and Mechanical Properties:*

All manufactured samples were tested for compressive strength, flexural strength, density, water absorption and initial rate of absorption. The tests were conducted according to the BS 3921:1985 (1985) whilst the dry density test was based on the Australian / New Zealand Standard Australian 4456.1:2003 [1]. The results reported are the mean of five values.

*Thermal Conductivity:*

Thermal conductivity was tested using a hot guarded plate method. This device can measure the thermal conductivity of a material when a layer of materials of known thickness and area are heated from one side by an output. This test also measures the ability of a material to conduct heat. Following the requirement of BS EN ISO 8990 (1996), the experiment was run for 100 minutes for each sample and the great data was recorded every one minute.

*Energy Measurement:*

The specific energy for bricks firing can be calculated by dividing energy used for firing (MJ) by mass of the brick (kg). Specific energy varies from 2 MJ/kg to 10 MJ/kg depending on the type of brick and kiln used. In the present investigation, the firing energy for control brick and another three different types of POW brick were calculated by assuming that the specific energy was 2 MJ/kg as (an estimated minimum value). POW bricks were calculated by taking into account the mass of the incorporated POW and the calorific value of the waste. This was necessary to facilitate brick firing. The calorific value of PKS was 11.2 MJ/kg while the calorific values of POFA and PF were 13.6 MJ/kg and 16 MJ/kg respectively. Hence, the estimated firing energy saved from the incorporation of wastes into the fired clay bricks was calculated.

## RESULTS AND DISCUSSION

*Dry Shrinkage:*

As shown in Fig. 2, PKS brick had the highest value of dry shrinkage (3.53%), followed by POFA brick (2.62%) and PF brick (2.34%). The lowest value of dry shrinkage was recorded for control brick (1.97%). To clarify, POW had increased shrinkage properties as their water demand was much higher. Adding POW into a fired clay brick thus, amplified its drying and firing shrinkage capacity due to increased water evaporation along the process. In other words, a POW brick tend to shrink more during firing. Their shrinkage value however, still complied with the preferable shrinkage properties (2.5% to 4%).

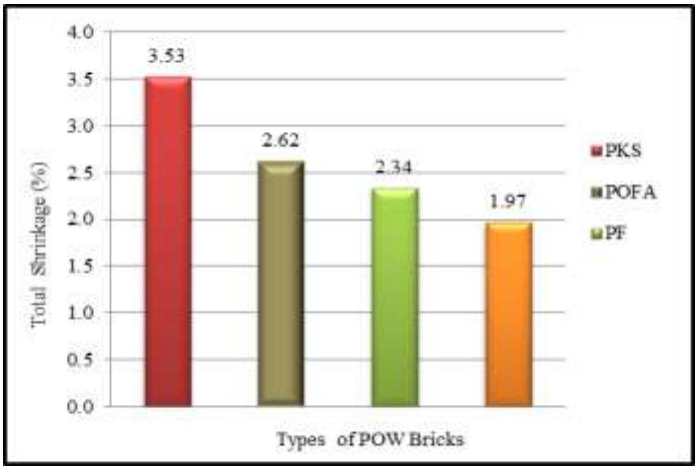


**Fig. 2:** Effect of POW content on total shrinkage of bricks.

*Dry Density:*

Fig. 3 shows that control brick had the highest dry density (1792.46 kg/m$^3$). This was followed by POFA brick (1760.98 kg/m$^3$) and PKS brick (1715.46 kg/m$^3$). PF brick had the lowest value of density (1711 kg/m$^3$). Bricks with additional fibres had lower density because their natural fibres tend to burn away at high temperature during a firing process.

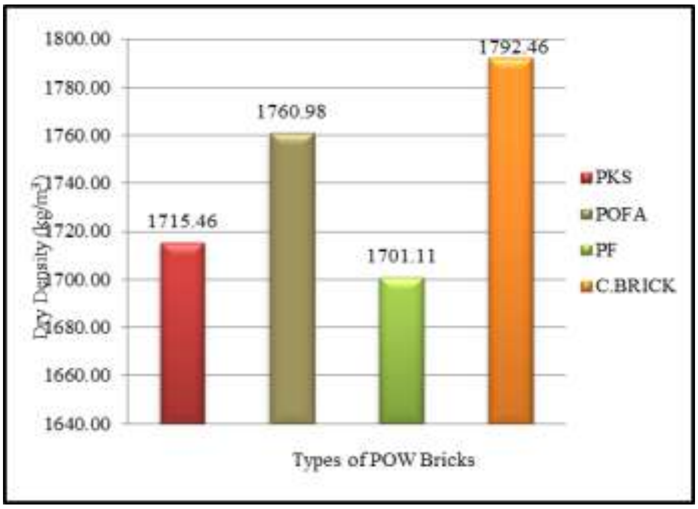

**Fig. 3:** Effect of POW content on bricks' dry density.

Generally, a brick of higher density has better compressive strength. However, lower-density bricks have lower structural dead load but offering lightweight bricks, lower transport cost and are easier to handle [10], This poses greater advantage in construction. The fibre bricks with lower densities are potentially useful for thermal isolation of building, especially in regions with extreme climatic changes [6]. All things considered, the POW brick's lower density value still met with the above mentioned requirement.

*Initial Rate of Suction (IRS):*

According to the BS 3921:1985 (1985), IRS values between 0.25 kg/m$^2$.min and 1.5 kg/m$^2$.min generally produces good bonding strength when used with appropriate mortar designation. High suction bricks can rapidly absorb water from mortar thus, impair bond properties. Water is needed for proper hydration of cement, which bonds mortar with the brick. On the other hand, a low suction brick does not absorb water as much. As a result, the surplus water rises to the mortar's surface, resulting in poor initial and final bonding strength.

Fig. 4 shows that the highest IRS value for 3% of POW was PF brick (6.46 kg/m$^2$.min), followed by PKS brick (4.57 kg/m$^2$.min). Control brick exhibited larger differences (4.38 kg/m$^2$.min) while the lowest value was obtained for POFA brick (3.82 kg/m$^2$.min).

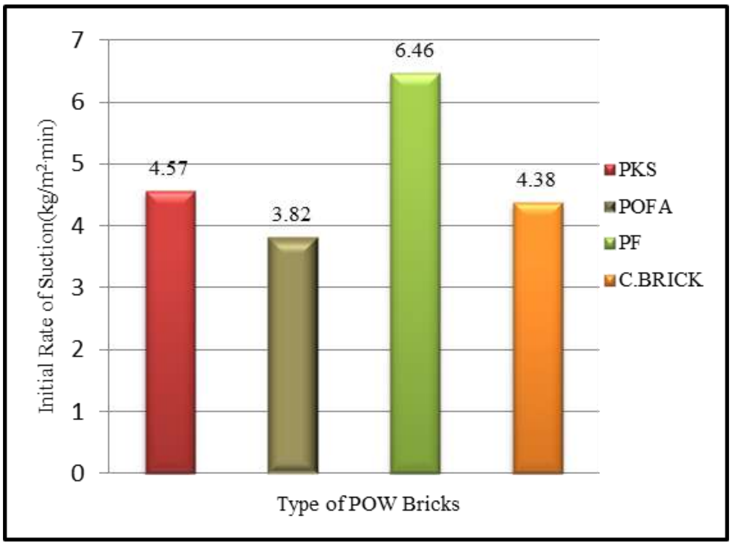


**Fig. 4:** Effect of POW content on IRS of bricks.

PF brick exhibited the highest value of IRS because of its highly porous natural fibre, which would burn away at high temperature during a firing process. In any event, a highly porous brick absorbs more water compared to bricks of lower porosity. The IRS and the total water absorption capacity determine the performance and durability of a brick. Unacceptable high IRS values and water absorption can lead to a change of volume that may risk cracking and consequently, structural damage to a building. Since the BS 3921:1985 (1985) does not state the limit of an IRS value, a POW brick can still be considered for building construction.

*Compressive Strength:*

A compressive strength machine with a capacity of 3000 kN was used to test the compressive strength of POW and control brick. The POW bricks were imposed with a compression load until they failed. A compressive strength is the maximum load that a brick can carry before failure. Based on the BS 3921:1985 (1985), the minimum requirement for a brick should not be less than 5 kN/mm$^2$.

Fig. 5 shows that all bricks carried the capacity above the minimum BS 3921:1985 (1985) requirement. Control brick obtained the highest compressive strength (22.88 kN/mm$^2$), followed by POFA brick (16.82 kN/mm$^2$) and PKS brick (16.8 kN/mm$^2$) as shown in Fig. 6. In general, brick with higher density corresponds with higher strength and water absorption capacity. Regardless, a faster and longer mixing process will yield a finer mixture with an improved compressive strength. PF brick had the lowest compressive strength (11.88 kN/mm$^2$) because of its high porosity compared to other bricks. In any case, increased porosity reduces the compressive strength of a brick due to lower density. Higher density brick is suitable to be used as wall or support reaction that can withstand loads. It can be concluded that by increasing the used of palm fibre in a brick, its compressive strength and density will completely decrease due to the increased porosity. The brick with lower density not less than 5 kN/mm$^2$ could still be used as a wall as long as it fulfills the requirement of the standard.

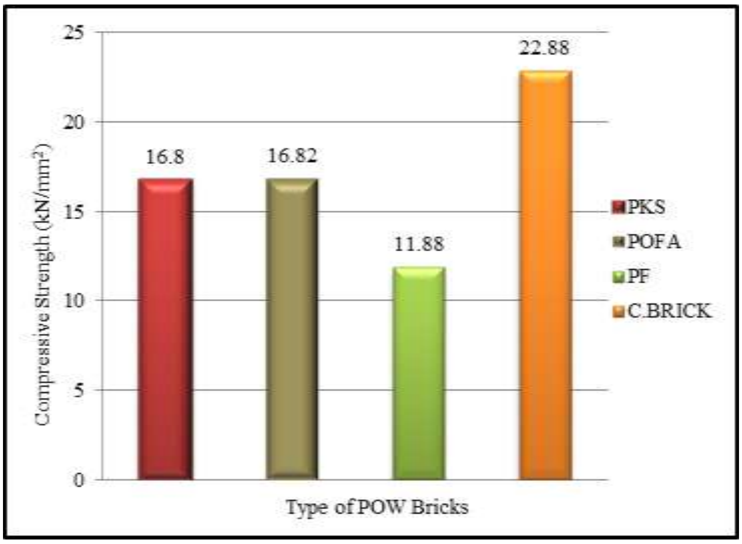


**Fig. 5:** Effect of POW content on compressive strength of bricks.

a) Control brick

b) PKS brick

c) POFA brick

d) PF brick

**Fig. 6:** Appearance of control brick, PKS brick, POFA brick and PF brick after compressive strength.

*Thermal Conductivity:*

Fig. 7 shows that control brick had the highest value of total thermal conductivity (0.9667 W/m.$^{o}$K), followed by POFA brick (0.9638 W/m.$^{o}$K) and PKS brick (0.9283 W/m.$^{o}$K). On the contrary, PF brick had the lowest thermal conductivity value (0.8828 W/m.$^{o}$K). This was because porosity played an important role in determining the value of thermal conductivity.

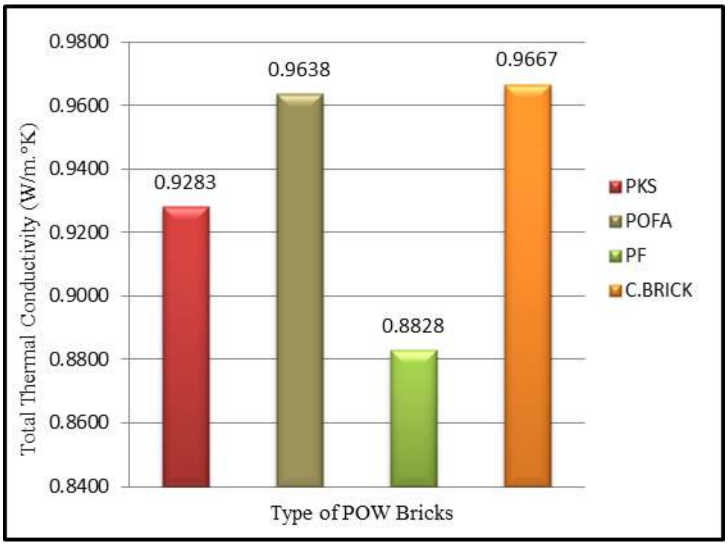


**Fig. 7:** Effect of POW content on thermal conductivity of bricks.

Porosity influences the value of thermal conductivity because of the existence of space between brick particles. Air resides within these spaces, making brick a bad heat conductor. The value of dry density of control brick was 1792.46 kg/m$^3$ while POFA brick was 1760.98 kg/m$^3$, PKS brick was 1715.46 kg/m$^3$ and PF brick was 1701.11 kg/m$^3$. From the comparison between the bricks' density and thermal conductivity graph, it could be concluded that the value of density would influence the value of thermal conductivity. Decreasing density value would decrease thermal conductivity value as well.

*Energy Efficiency:*

Fig. 8 shows that PF brick had the highest percentage of energy saved (43.14%), followed by PKS brick (37.4%) and POFA brick with (37.06%). Control brick recorded the lowest percentage of energy saved as it did not contain calcium oxide. The Calcium oxide (CaO), commonly identified as the quick or burnt lime, is known to facilitate a combustion process. For this reason, the PF, POFA and PKS brick had a higher percentage of saved energy compared to control brick. The percentage of calcium oxide (CaO) in PF was 15%, while in PKS was 14.3%. POFA had 11.10% of CaO and control brick had 0%. In addition, the high calorific value in POW bricks would ease the firing process. Given these points, the percentage of energy saved could be increased by increasing the quantity of palm oil waste in a brick.

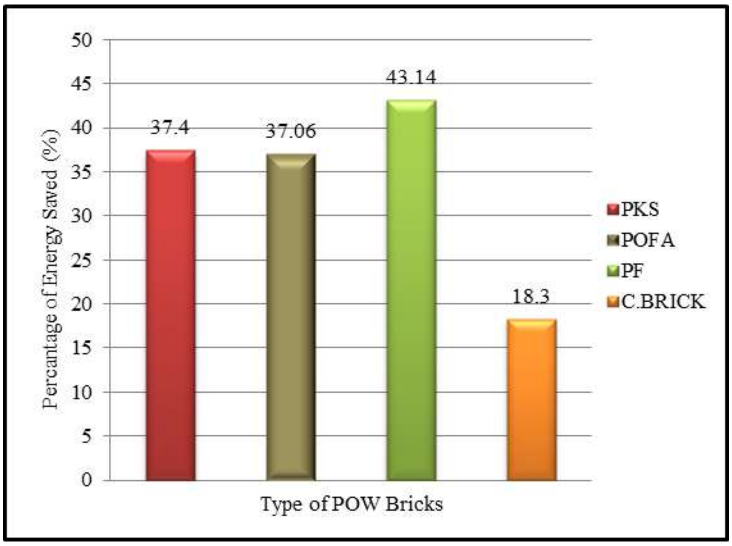


**Fig. 8:** Effect of POW content on percentage of energy saved by bricks.

*Physical and Mechanical Properties:*

Table 3 shows the physical and mechanical properties of the three different types of POW and control brick. Based on the results from the present study, different type of POW exhibited different physical and mechanical properties. In terms of compressive strength, control brick remained the best, with 22.88 kN/mm$^2$ compared to POFA (1.82 kN/mm$^2$), PKS (16.80 kN/mm$^2$) and PF (11.88 kN/mm$^2$). Despite this limitation, other properties of POW bricks still complied with the requirement. The reason control brick remained the best in terms of compressive strength was because it was the most compact brick compared to PKS, POFA and PF brick. The control brick however, was poor in terms of energy saving as it took a longer combustion process. In this case, it only managed to save 18.3% of the energy.

**Table 2:** Physical and mechanical properties of three different types of POW and control brick.

| Type of waste | Mixture identification (% POW) | Compressive Strength (kN/mm$^2$) | Initial Rate of Suction (kg/m$^2$,min) | Dry Density (kg/m$^3$) | Dry Shrinkage (%) | Thermal Conductivity (W/m.$^o$K) | Energy Saved (%) |
|---|---|---|---|---|---|---|---|
| - | 0 | 22.88 | 4.26 | 1792.46 | 1.97 | 0.9667 | 18.30 |
| PKS | 3 | 16.80 | 4.57 | 1715.46 | 3.53 | 0.9283 | 37.40 |
| POFA | 3 | 16.82 | 3.82 | 1760.98 | 2.62 | 09638 | 37.06 |
| PF | 3 | 11.88 | 6.46 | 1701.11 | 2.34 | 0.8828 | 43.14 |

There was only a small difference in terms of physical and mechanical properties of the POFA and PKS brick. In terms of compressive strength, the different between POFA and PKS was just 0.02 kN/mm$^2$. However, POFA appeared to have a higher value of dry density compared to PKS as this property is influenced by the index of calcium oxide in both chemical compositions; POFA contained 11.10% less compared to PKS. So the efficiency during combustion process for PKS was better than POFA because of the existence of calcium oxide, which facilitated the combustion process.

Although PF brick was not as good as control brick, POFA brick and PKS brick in terms of physical properties, it provided the greatest energy saving. Regardless, the brick's compressive strength, dry density and thermal conductivity value still comply with the BS 3921:1985 (1985) and thus, could serve a different function such as a non-loading wall.

*Conclusion:*

The production of POW has been a problem in the palm oil industry. Often the accumulating wastes were not reused and further, disposed onto landfills and caused another environmental issue. POW was worth being recycled as bricks as this could reduce pollution apart from becoming a building material. The purpose of this study was to determine the possibility of incorporating three types of different palm oil waste (PKS, POFA and PF) into a fired clay brick. The utilization of POW into a fired clay brick had made those bricks stable enough to function for various purposes in addition to reducing energy consumption during firing. In conclusion, PKS, POFA and PF are highly potential wastes to be incorporated into a fired clay brick as it can produce a more lightweight brick with improved thermal properties and energy efficiency.

## ACKNOWLEDGMENT

The results presented in this paper are part of an ongoing research on Recycling Palm Oil Waste into fired clay brick. The authors would like to thank University Tun Hussein Onn Malaysia, for the facilities of this study.

## REFERENCES

[1] Australian/New Zealand Standard AS/NZS. Method 1 4456.1 (2003).
[2] Awal, A.S.M.A. and M.W. Husin, 2011. Effect of palm oil fuel ash in controlling heat of hydration of concrete. Proc Eng., 14: 2650-2657.
[3] British Standard Institution (BS). British standard methods of test for soils for civil engineering purposes 1990. Part 2: Classification Tests 1337. London, British Standard Institution, pp: 320.
[4] British Standard Institution (BS). Thermal Insulation - Determination of Steady- State Thermal Transmission Properties - Calibrated and Guarded Hot Box 1996. BS EN ISO 8990. London, British Standard Institution.
[5] British Standard Specification for Clay Bricks. BS 3921 (1985).
[6] Chan, C.M., 2011. Effect of natural fibres inclusion in clay bricks: physico-mechanical properties. Int J Civ Environ Eng, 51-55.
[7] Demir, I., 2005a. An investigation on the production of construction brick with processed waste tea. Build Environ, 41(9): 1274-1278.
[8] Demir, I., 2008b. Effect of organic residues addition on the technological properties of clay bricks. Build Environ., 28(3): 662-667.
[9] Folaranmi, J., 2009. Effect of additives on the thermal conductivity of clay. Leonardo J Sci., 14: 74-77.
[10] Kadir, A.A. and A. Mohajerani, 2010. Possible utilization of cigarette butts in lightweight-fired clay brick.

Int J Civ Environ Eng., 2(3): 118-122.
[11] Koroneos, C. and A. Dompros, 2007. Environmental assessment of brick production in Greece. Build Environ, 42: 2114-2123.
[12] Malaysian Palm Oil Board (MPOB). Malaysian Oil Palm Statistics, (on-line) http://econ.mpob.gov.my/economy/annual/stat2007/Area1.htm: Retrieved on 25 June 2008.
[13] Mannan, M.A. and C. Ganapathy, 2004. Concrete from an agricultural waste-oil palm shell (OPS). Build Environ., 39(4): 441-448.
[14] Olanipekun, E.A., K.O. Olusola and O. Ata, 2006. A comparative study of concrete properties using coconut shell and palm kernel shell as coarse aggregates. Build Environ., 41(3): 297-301.
[15] Ortiz. R.A., E. Villalobos and O. Fernandez, 1992. Mulch and fertilizer effects on soil nutrient content, water conservation and oil palm growth. ASD Oil Palm Papers, 6.
[16] Ramble. R., S. Shaler and A. Jamaludin, 2002. Properties of medium density fibreboard from oil palm empty fruit bunch fibre. J Oil Palm Res., 14(2): 34-40.
[17] Saiah, R., B. Perrin and L. Rigal, 2010. Improvement of Thermal Properties of Fired Clays by Introduction of Vegetable Matter. J Build Phys., 34(2): 124-142.
[18] Teo, D.C.L.M., M.A. Mannan, V.J. Kurian and C. Ganapathy, 2007. Lightweight concrete made from oil palm shell (OPS): Structural bond and durability properties. Build Environ., 42(7): 2614-2621.
[19] Turgut, P. and H.M. Algin, 2006. Limestone dust and wood sawdust as brick material. Build Environ., 42: 3399-3403.